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The Modern Method of Firing Clay Wares

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With the general unsettled industrial condition throughout the country, and the desire of all to have business return to a sound footing, one of the most desirable steps is a reduction of manufacturing costs. Labor is objecting to wage reduction and probably with some justification unless with an absolute assurance that selling prices will be promptly reduced in proportion.

INCREASED EFFICIENCY DESIRABLE

There is another means whereby manufacturing costs may be reduced, i. e., by increasing production efficiency and by the reduction of waste. In the case of fuel, with which this country has been blessed in a goodly measure, greater efficiency in its use will not only accomplish a reduced manufacturing cost, but will conserve one of the most valuable natural resources this country possesses.

The ceramic industry (that industry involving the manufacture of non-metallic products from inorganic materials, in the process of which high temperatures are employed) has for many years wasted more fuel than any other industry in the country. Any method or apparatus, therefore, that can be developed to make the firing of ceramic wares more efficient should be a very welcome thing to the country at large.

PRESENT PRACTICE

To give some concrete examples of the fuel consumption in the firing of clay ware in the ordinary periodic kilns in general use at this time:

Ware	Bituminous Coal	Fuel Oil	Natural Gas
1000 high grade building brick	1500 lbs.	2.6 bbl.	19,000 cu. ft.
1 ton terra cotta	950 lbs.	1.65 bbl.	11,800 cu. ft.
100 dozen pieces table ware (dishes)	780 lbs.	1.4 bbl.	9,750 cu. ft.

It should be explained that in firing clay wares in periodic kilns, the greatest fuel losses are in the heat carried out of the kiln in the highly heated combustion gases; the heat radiated from the exterior of poorly insulated side walls and crown arch and the heat left in the ware and kiln structure at the end of the burn. The average losses, as calculated from carefully conducted tests, are shown below:

Heat taken up by ware.....	12%
Heat lost in combustion gases.....	25%
Heat lost in ashes.....	4%
Heat taken up by kiln and lost by radiation	59%

If the necessary means were employed, a large part of the first expenditure could be reclaimed. A regenerative or recuperative provision would greatly reduce the second loss, while a thorough heat insulation of the structure would reduce the radiation loss materially.

THE CONTINUOUS CAR TUNNEL KILN

With the idea of reducing the heavy heat losses noted, there has developed a kiln structure, known generally as the "Continuous Car Tunnel Kiln," or the "Railroad Tunnel Kiln." With the use of this

type of kiln, the fuel consumption is only from 15 to 30 per cent of the average periodic kiln requirement and, therefore, other things being equal, the tunnel kiln is going to take a very prominent part in the future firing of clay wares.

In this type of kiln (shown in plan in Fig. 1) the ware is mounted on iron or steel cars, having refractory platforms. The entire length of the kiln is filled at all times with a train of these cars, which keeps moving practically continuously from the charging end toward the discharging end. A series of furnaces are provided on each side of the kiln approximately midway of its length and the combustion gases from these furnaces pass immediately into the tunnel proper and come into direct contact with the ware setting. These gases then proceed toward the draft ports near the charging end of the kiln,—traveling in a direction opposite to the movement of the cars. Fresh air from the pressure fan is introduced through a blast head just underneath the kiln crown at the discharging end. This air, which is introduced largely for cooling purposes, takes the heat from the fired ware and upon reaching the furnace section of the kiln functions as secondary air for combustion—mingling with the combustion gases from the furnaces and proceeding with these gases to the draft ports. From this it will be seen that if the kiln has sufficient length, the combustion gases will leave the kiln at a relatively low temperature. Furthermore, the ware leaving the kiln will have given up most of its heat to the incoming fresh air. The only other heat loss of any consequence is radiation, which is probably taken care of in a better manner than is done on any other kind of ceramic kiln, i. e., at the center or high temperature section of the kiln the walls and crown have heavy insulation; the intermediate portions are insulated to a lesser degree and the ends are only slightly insulated.

HISTORY

This kiln originated in Europe—the first one appearing at Vincennes, France, in 1751, and being used for firing overglaze colors. The first kiln of this type proposed for firing brick was covered by a Danish patent in 1840. This was followed by a kiln which was described in a German publication in 1848, and which consisted of merely the heating end and the combustion compartment, but no cooling end. When the ware had passed through the high temperature zone it was removed and placed in another tunnel, or compartment, to cool. Other designs embodying various ideas of construction were then brought out, some of them not differing greatly from the modern kiln.

In 1877 Otto Bock was granted a German patent and he built about sixty of these kilns—most of them proving failures. Within the last fifteen years or so more successful kilns have been developed, particularly the kiln of the Faugeron type, and a number of these are now in successful operation in Europe.

The American history of this type of kiln seems to start with a kiln erected in Chicago about 1889 by J. C. Anderson for the firing of dry press brick. Mr. Anderson took out two patents about this time, both pertaining to the twin-tunnel type. He soon built another kiln at Long Island City, but neither kiln operated for any great length of time. In 1910 two kilns of the Faugeron type were built at Keasbey, N. J., and as these kilns are still in operation, it can probably be said that they are the first successful kilns built in this country. The muffle type of kiln was introduced to this country from England about 1915, and has been attended with considerable success, particularly in the burning of white wares. Other kilns have been brought out from time to time—some admitted failures and others with varying degrees of success.

A large number of patents have been issued in this country on tunnel kilns which have never been built. Information secured from the United States Patent Office in June, 1919, indicates that at that time there were in force sixty-three patents relating to the tunnel kiln and as many more which had already expired.

MODERN DEVELOPMENT

The tunnel kiln illustrated is located at the plant of the General Porcelain Co., Parkersburg, W. Va., and is used for firing a general line of low tension electrical insulators of both white and brown color. It is of the direct-fired type, and is equipped for using either natural gas or fuel oil or both together.

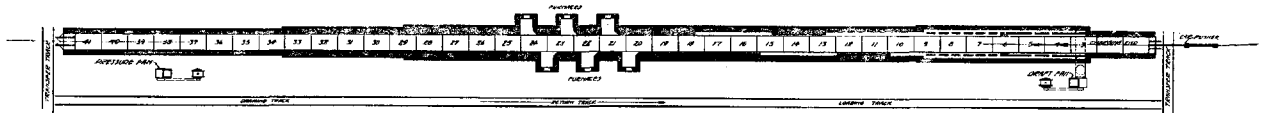


Fig. 1

The kiln proper is 4 ft. 6½ in. wide by 321 ft. long and holds fifty-two cars at one time. The setting of ware on each car occupies a space of 4 ft. 2½ in. wide by 5 ft. 1 in. high by 5 ft. 9 in. long. A car is charged every hour and the train moves at the rate of 1.2 in. per minute. At the present time the first four furnaces are being fired. Under this hand-

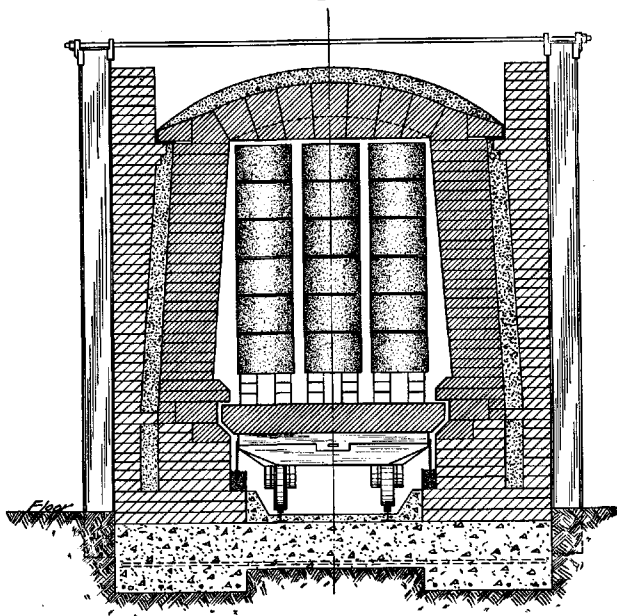


Fig. 2

ling of the kiln, the ware is under fire for thirty hours and twenty-two hours is given to cooling.

Fig. 2 is a typical cross section through the high-

temperature zone, near the furnaces and clearly illustrates several of the novel and patented features of this particular design of tunnel kiln.

Periodic kilns are usually either up or down-draft. The tunnel kiln is essentially a horizontal draft kiln. It is a well known fact in physics that hot gases tend to rise, and if hot gases are introduced into a room or compartment of any kind, these gases will promptly rise and flow laterally in the upper portions of such compartment. In the case of the tunnel kiln the hot gases tend to rise and flow underneath the crown toward the draft ports near the charging end. The usual result of this is that the upper part of the ware setting is subjected to greater heat work than the lower part, which is very evident from the quality of the ware discharged. Recognizing these facts, the author has provided in his kiln structure, obstructions to the free flow of gases underneath the crown (in Fig. 2, a depending baffle is employed), and also, the side walls are so battered as to give greater clearance for the flow of gases at the lower levels than near the top. Furthermore, the ware, or the placing of saggars (clay boxes) carrying the ware, is stilted up off the car platform, which permits a circulation of hot gases underneath the ware. The result of this arrangement is that with the greater amount of circulation taking place at the lower levels, a uniformity of temperature is secured over the entire cross section of the ware.

Firing losses (cull ware) in this design of kiln are practically eliminated as all ware passes through

the kiln at a uniform rate and all of it encounters uniform conditions of heating rate, maximum temperature and cooling rate.

CARS

The car frame is a single gray iron casting with a gridded top and with two double-flanged wheels and two flat-faced wheels,—both kinds being 12 inches in diameter. These wheels are equipped with caged roller bearings and each revolves on an individual axle.

On each side of the car is attached a depending steel plate, 3/16 inch thick, which runs in the sand-seal trough on each side of the kiln tunnel.

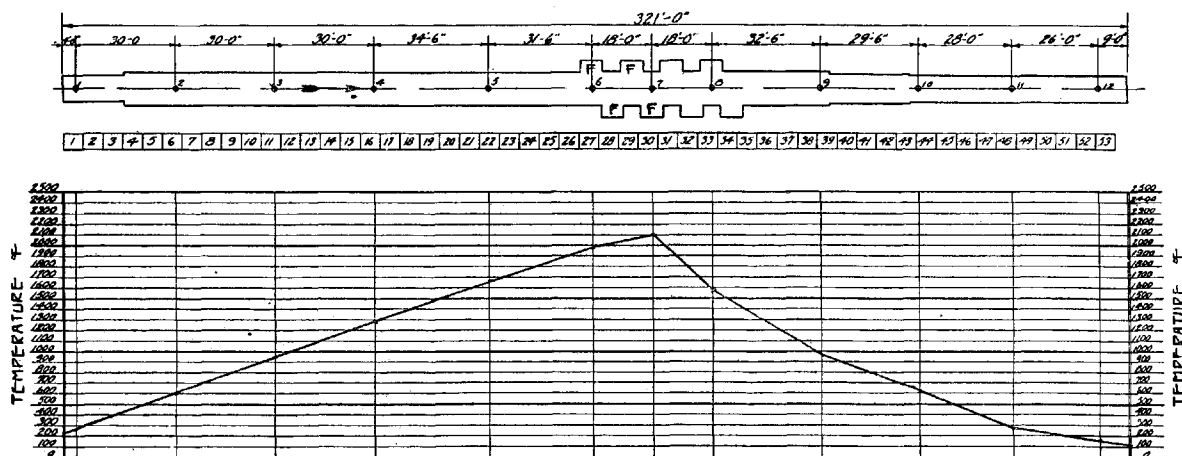
On top of the car frame is laid a No. 14 gage steel plate, which supports a 2½ in. layer of Sil-O-Cel (pulverized kieselguhr) and Portland cement (4:1 by volume.)

The car is then covered with specially shaped fireclay slabs, 9 in. thick,—the top surface being the finished platform.

CAR PUSHER

The hydraulic ram which is used to propel the train of cars through the kiln was designed by P. W. Ott of the Department of Mechanics and is far more simple and inexpensive than the hand-operated or mechanical device in general use.

This ram carries its oil for actuating in a reservoir in its own base. A single plunger oil pump, driven by a back-geared one-half horsepower variable speed electric motor is employed. The plunger has a stroke several inches longer than the car and returns automatically at the end of its stroke, through



TEMPERATURE RECORD
HARROP CONTINUOUS TUNNEL KILN

Oct. 20, 1921 HOUR 11⁰⁰ a.m. CAR SCHEDULE 12¹/₂ hr CONE 12 TAKEN BY J. C. Brown

Fig. 3

the operation of a trip and a special three-way valve.

This pusher operates under a pressure of 600 pounds per square inch and the total pressure necessary to move the train of cars is approximately 8,000 pounds.

KILN CONSTRUCTION

Carrying the entire structure is a well reinforced concrete foundation 18 in. thick under the side walls. The outer masonry walls are preferably of soft burned porous common brick laid in cement-clay-sand mortar. The lining of the tunnel (arch and sides) and the furnaces are of the highest grade fire brick carefully laid in a minimum amount of fire clay mortar. Between the lining and the outer wall is heat insulating material which will be spoken of later. Special fire clay shapes are used wherever necessary, which results in a more solid structure and at the same time saves a considerable amount of the mason's time, which would otherwise be used in chipping and fitting.

A sand seal trough is provided in each side of the tunnel,—the outer confining wall of which is a ¼ in. by 8 in. steel plate, extending the full length of the kiln. These sand troughs in connection with the sand seal plates attached to both sides of the cars provide an effectual air seal between the tunnel proper, in which the firing takes place, and that portion of the tunnel beneath the car platforms. This seal is necessary, as it is quite essential that the hot gases from above are not drawn underneath the cars to injure the running gear and it is equally important that the draft in the tunnel proper does not draw cool air from beneath to chill the lower portions of the ware.

Longitudinal slots are provided in the side walls, in which the car platform fits rather loosely. The purpose of this is to intercept radiated heat, which would otherwise travel from the highly heated tunnel proper down onto the metal car frames and sand seals.

Any number of furnaces may be provided on

each side of the kiln,—depending upon the length of high temperature (or soaking) zone required for the particular ware. In all cases these furnaces have hollow walls. Air is circulated through these walls and then led to the burners or through the grates as preheated primary air for combustion.

Air is also forced through a low, wide flue over the arch of the entire cooling end of the kiln. This air is then led down over the furnace arches and finally delivered into the front of the furnaces as secondary air for combustion.

The furnace throat or connection between the furnaces and the tunnel is the full width of the furnace and in height extends from about 6 in. above the car platform to a point about three-fourths of the way up to the spring line of the tunnel arch.

The charging end is closed by a Kinnear rolling steel door, having a hole in its lower part through which the push rod is inserted for moving the cars. After the train has been moved one car length and the ram returned automatically to the starting position, the rolling door is raised, and a car of ware is pushed into the empty space in the kiln. The door is then dropped, the push rod put into place and the pusher started.

Before charging a car of green ware, a car of fired ware should always be removed from the discharging end to provide space for the movement of the train. On occasions this has been overlooked, with the result that the discharging end door has been broken down. For this reason the discharging end is now closed with double hinged steel doors which open automatically from the inside, should the necessity demand.

Steel angles 5 in. x 3 in. x ¾ in., running the full length of the kiln, are provided on each side to take the thrust of the kiln arch. Vertical buckstays of 6 in. I beams are spaced at approximately 6 ft. intervals along the sides of the kiln,—being anchored at their lower ends in steel U straps cast into the concrete foundation and held together at their upper ends

with $\frac{3}{4}$ in. diameter tie rods passing through unfinished gray iron castings slipped over the tops of the I beams.

The side walls are provided with small peep holes, having iron frames and covers, to allow an inspection of the interior of the kiln and ware while under fire, as well as the pyrometric cones, used in determining the real heat work being done in the kiln. These holes are also used for taking pressure and draft readings, as well as gas samples for analysis, from the tunnel.

INSULATION

As radiation is one of the large losses in periodic kilns special care has been taken in this kiln to reduce this to a minimum.

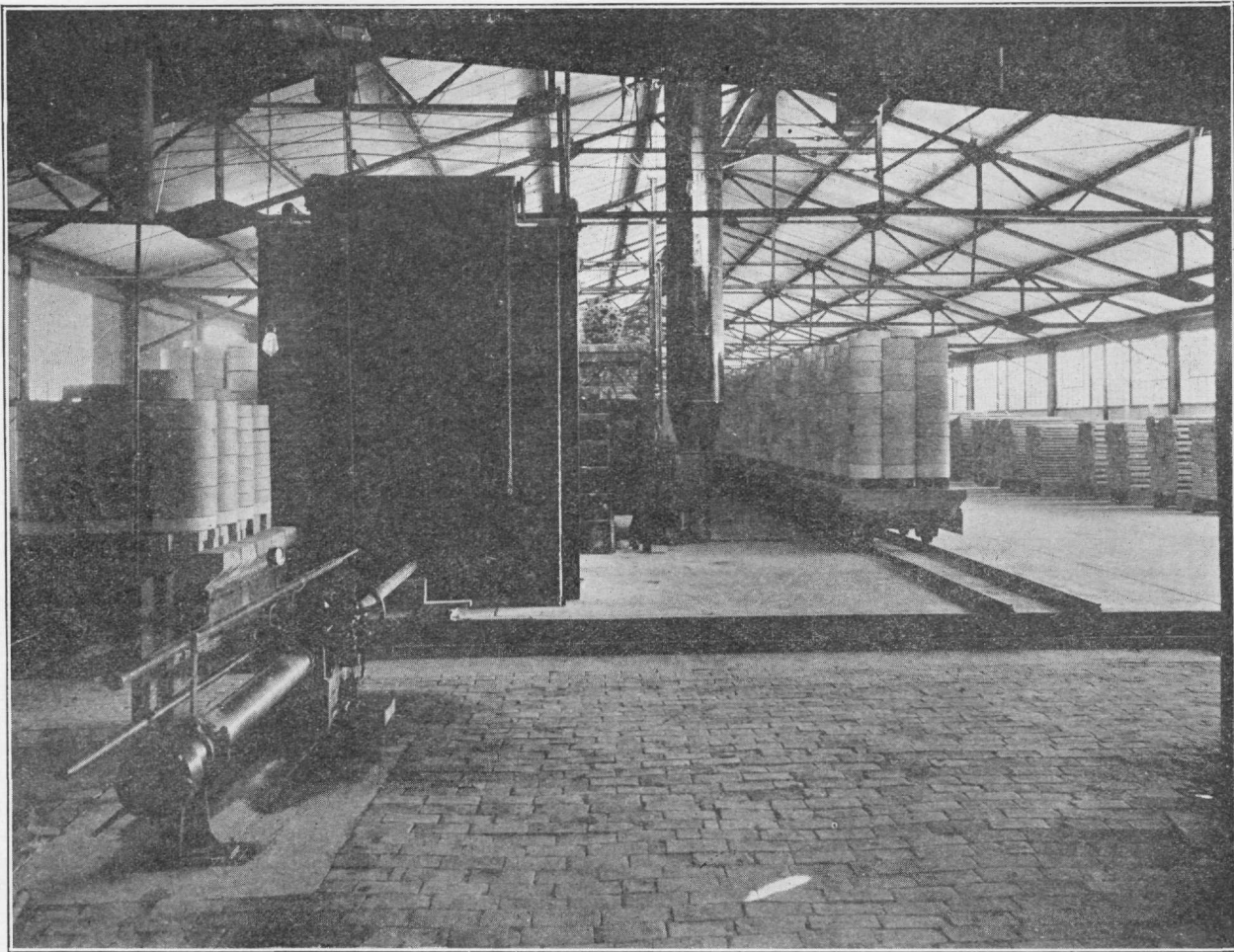
The best non-conductor of heat at high tempera-

Towards the ends of the kiln the insulation is reduced to $2\frac{1}{2}$ inches in thickness and at the extreme ends no special insulation is employed.

EXPANSION

Expansion of a masonry structure, due to the raising of the interior to high temperatures, is a very difficult thing to handle. The expansion and contraction of a periodic kiln are very hard on the structure. It can be readily appreciated, therefore, what a serious problem expansion is in a structure over 300 ft. long.

In this kiln, expansion joints are provided about every 50 ft. in the foundation, the side walls and the tunnel arch,—the several joints not being permitted to fall in the same vertical plane. The expansion joints in the side walls are “ship-lapped.”



Charging End of Kiln

tures that has been developed is kieselguhr (infusorial or diatomaceous earth). This is readily available now in its natural state under the trademarked name of Sil-O-Cel and can be gotten either in the form and size of standard fire brick or as powder. One inch in thickness of this material is equivalent in insulating value to 12 inches of ordinary fire brick masonry. This material may be used in the walls either in the form of brick or block, or as a powder. Powder is probably preferable, as it leaves no large voids or air spaces between the common brick wall and the fire brick lining.

In the furnace or high temperature zone, the side walls have $4\frac{1}{2}$ inches of heat insulating material. The arch in this zone is also covered with the same amount of insulation.

In every fifth mortar joint of the common brick side walls are placed $\frac{1}{16}$ in. x 1 in. steel strips, so that when it becomes necessary to close down the kiln, the several sections of the kiln wall will contract as monoliths, rather than develop unsightly diagonal cracks.

The track walls have mitred, spaced joints and slotted bolt holes to take care of the expansion in these members.

FIRING EQUIPMENT

Only four of the eight furnaces are being used in the Parkersburg kiln at this time, these being fired with natural gas.

A No. 3 Maxon Premix burner is installed in front of each furnace. These burners consist of a small centrifugal blower operated by a direct-con-

nected one-half horsepower motor. Gas and pre-heated air are drawn into the blower which thoroughly mixes the two and then delivers the mixture at the high velocity into the furnaces. About 90,000 cu. ft. of gas are consumed per 24 hours.

Equipment is also installed for the firing of fuel oil during periods of gas shortage. The low pressure system is used,—the Maxon blowers supplying the air. The Viking rotary oil pump, operated by a direct-connected one-fourth horsepower motor is used to supply the oil pressure. This pump has a capacity of $2\frac{1}{2}$ gallons of oil per minute, delivered at 35 lbs. pressure through a $\frac{3}{8}$ in. diameter pipe to the oil heater. The oil pumping and straining equipment is in duplicate, so that continuous operation may be assured.

POWER

The draft fan is a centrifugal steel plate exhauster. The wheel is "over-hung" and the shaft is provided with water-cooled bearings. A 10 horsepower motor is provided for this fan.

The centrifugal steel plate pressure fan, which supplies the air for cooling and for combustion, is operated by a $7\frac{1}{2}$ horsepower belted motor.

Aside from the firing equipment, the total power actually required to operate the kiln is probably not in excess of 12 horsepower.

PYROMETRIC INSTALLATION

Electric thermocouples are inserted into the tunnel through the center of the arch,—noble metal couples being used in the high temperature parts and base metal couples in those parts, where the temperature does not exceed 1500° F. The cold end junctions of all thermocouples are buried in Sil-O-Cel in 12 in. square boxes, so as to prevent fluctuations in the pyrometer readings.

All pyrometer wiring is carried in conduits.

The instruments used are the wall type of indicating galvanometer and the recording galvanometer. The former is used in securing the temperatures for the gradient records and the recorder is used for checking up temperatures during the night and on holidays, to see whether the firemen have been watchful or not. It furthermore enables the firemen on the different shifts to compete with each other in securing constant temperatures during their tricks, which is indicated by a straight, non-waving line.

CONCLUSIONS

There are several excellent arguments favoring this type of kiln, which point very strongly towards its becoming the real kiln of the future. These might be enumerated as follows:

(a) *Uniformity of firing conditions.* In firing periodic kilns, the time-temperature curve will depend upon the firemen, the condition of the kiln, the setting in the kiln, the fuel, the weather and perhaps some other influences. In the tunnel kiln, it is necessary only to hold a certain fixed temperature, while the rate at which the ware is heated is controlled mechanically, and is dependent upon the rate at which the cars are charged.

(b) *Economy of fuel.* The combustion gases can be cooled to practically any degree, (dependent upon the length of the kiln), before being discharged into

the atmosphere. The fired ware, moving slowly toward the discharge end, gives up its heat to incoming secondary air for combustion and can be cooled to practically any temperature, (again dependent upon kiln length). A saving in fuel of from 70 per cent to 85 per cent over periodic kiln operation can be figured on.

(c) *Economy of labor.* All placing of ware is done at one general location, as is also the unloading of the cars. The firing of all fuel is centralized. Cleanliness and order are far easier than with other types of kilns.

(d) *Construction cost lower than for either periodic kilns or moving-fire-zone continuous kilns of equal capacity.* The heaviest construction and greatest heat insulation is provided at the high temperature zone—less insulation and lighter construction towards the ends. Every feature and part of the structure is in use at all times. In the chamber continuous kiln, for instance, all chambers must be equipped with full flue systems and other equipment, which are not fully made use of during more than half the time, and, furthermore, all parts of this kiln must be heavily constructed and well insulated.

(e) *Lower cost of maintenance.* Expansion and contraction, due to the periodic heating and cooling of periodic kilns as well as continuous kilns with moving fire zone, result in considerable damage to the masonry. In the continuous tunnel kiln the structure expands when being brought up to heat and contraction takes place only when it becomes necessary to close down the kiln.

In periodic kiln firing a large mass of ware is heated by furnaces located around the outside of the mass. In order to reduce the firing time as much as possible, the temperature carried in the furnaces is necessarily exceedingly high, which results in severe punishment to the furnace linings. In the case of the tunnel kiln, a relatively small mass of ware gradually approaches the high fire zone. It is possible to have far greater furnace power per unit mass of ware, with the result that it is not necessary to have a furnace temperature as is the case with the periodic kilns. The advantage is evident.

The purpose of any kiln is to generate heat from the fuel provided and to enable an efficient and prompt transfer of this heat to the ware being fired. Also, it is equally important that all the ware being fired shall be subjected to practically the same degree of heat, so as to secure uniformity of the fired product. There is still a third requirement, which cannot be given too much consideration, namely, capacity of the kiln. Several of the tunnel kilns now being advocated are able to fire ware uniformly, if the ware passes through them slowly; but when the rate of passage of the ware is increased, and particularly if the ware is massive, uniformity of quality is greatly reduced.

In concluding, it should be stated that the kiln at Parkersburg required four and one-half months to build and the cost of the kiln structure and equipment complete in every respect was about \$55,000. W. E. Cramer, Cer. E. 1920, had entire charge of the construction of the kiln as well as the Milliken fabricated steel kiln building which is 60 ft. wide by 350 ft. long. This is the third kiln built by Mr. Cramer since his graduation from Ohio State.